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Using X-ray imaging to study thermal-induced changes in food

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Motivation for X-ray imaging of food

The food quality in many food processes relies greatly on the structural changes that take place during heating or freezing of the food product. So far, it has only been possible to study these changes indirectly but recent new X-ray imaging modalities allow for direct visualization. We present preliminary results of structural changes by heating of bovine meat and freezing of berries inspected with X-ray phase-contrast and dark-field imaging.

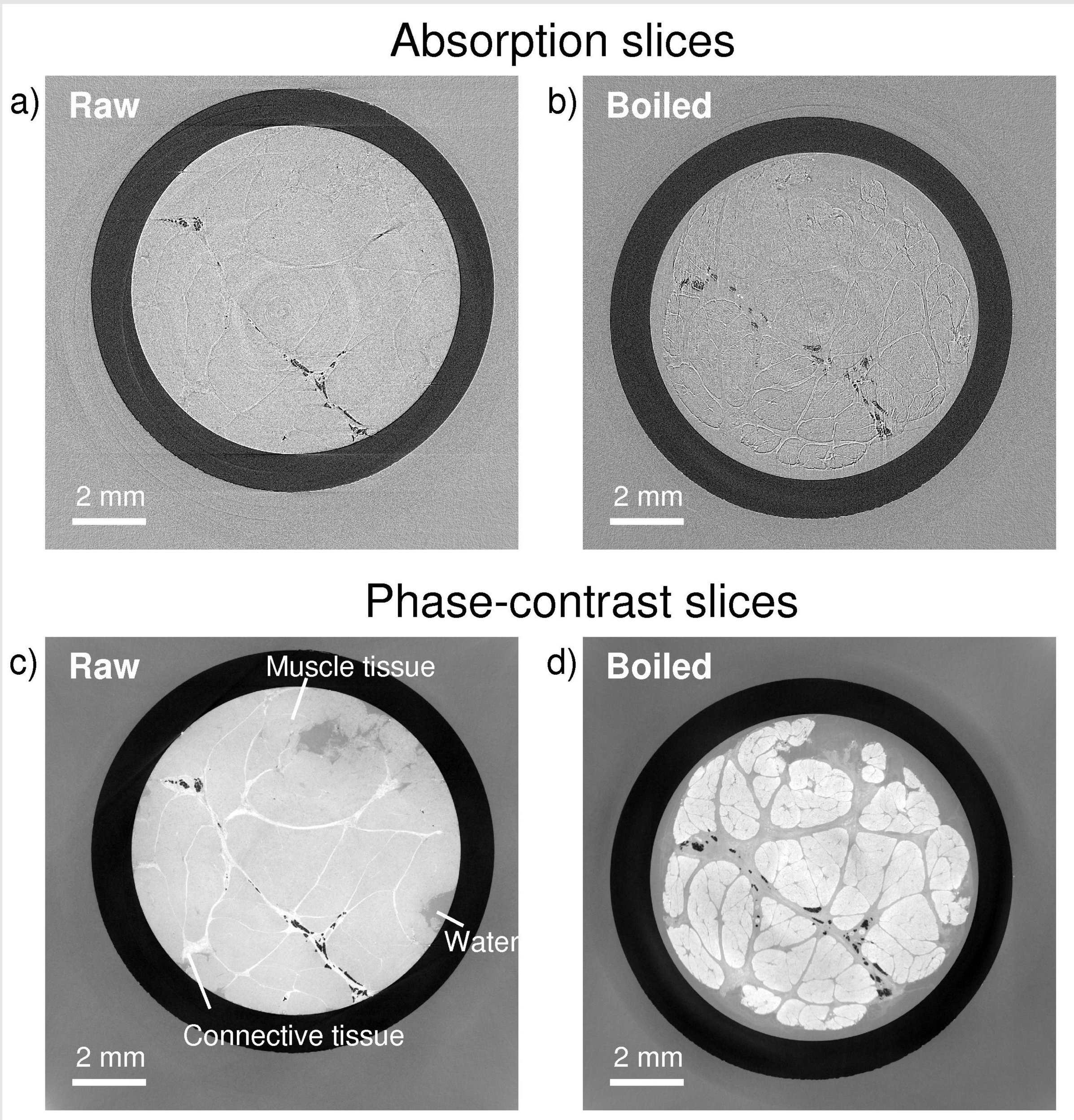
Outlook

Phase-contrast and dark-field imaging show potential for direct visualization of thermal-induced structural changes in food products.
Expanding on these preliminary findings, dark-field imaging may be of interest in industrial food inspection to discern whether fruit has sustained freezing damages while phase-contrast tomography could become a new standard tool for basic Food Science research.

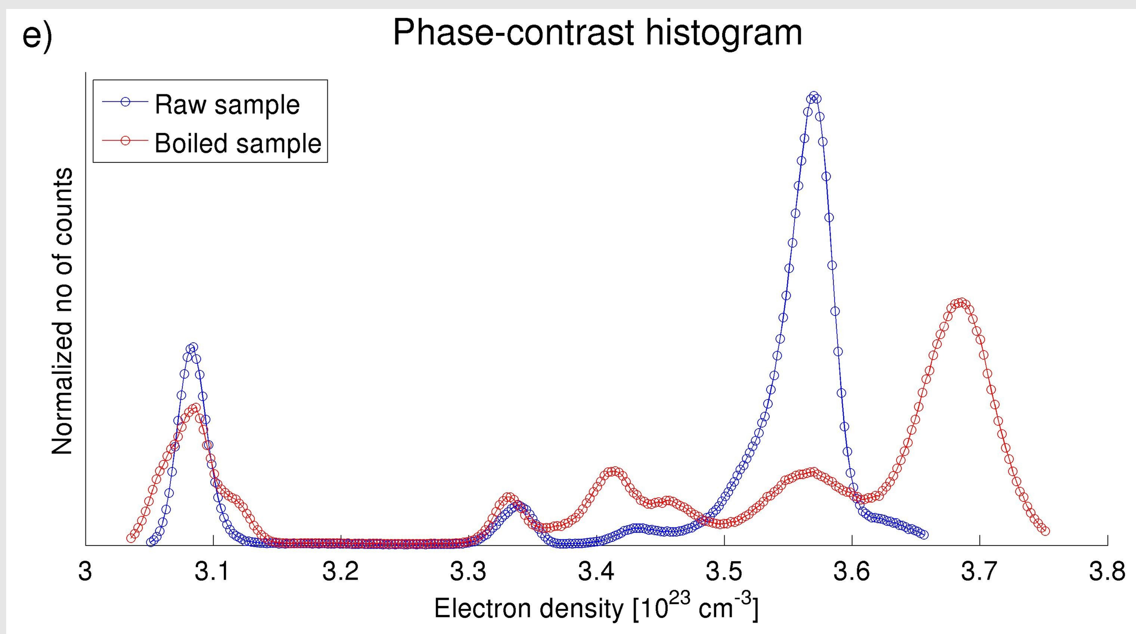
Heating meat

During heating of meat, several structural changes occur both in fat, muscle and connective tissue [1].

Most of the current knowledge on these changes have been obtained from indirect measurements. We propose to use X-ray phase-contrast imaging to visualize these changes directly – here illustrated for bovine meat.

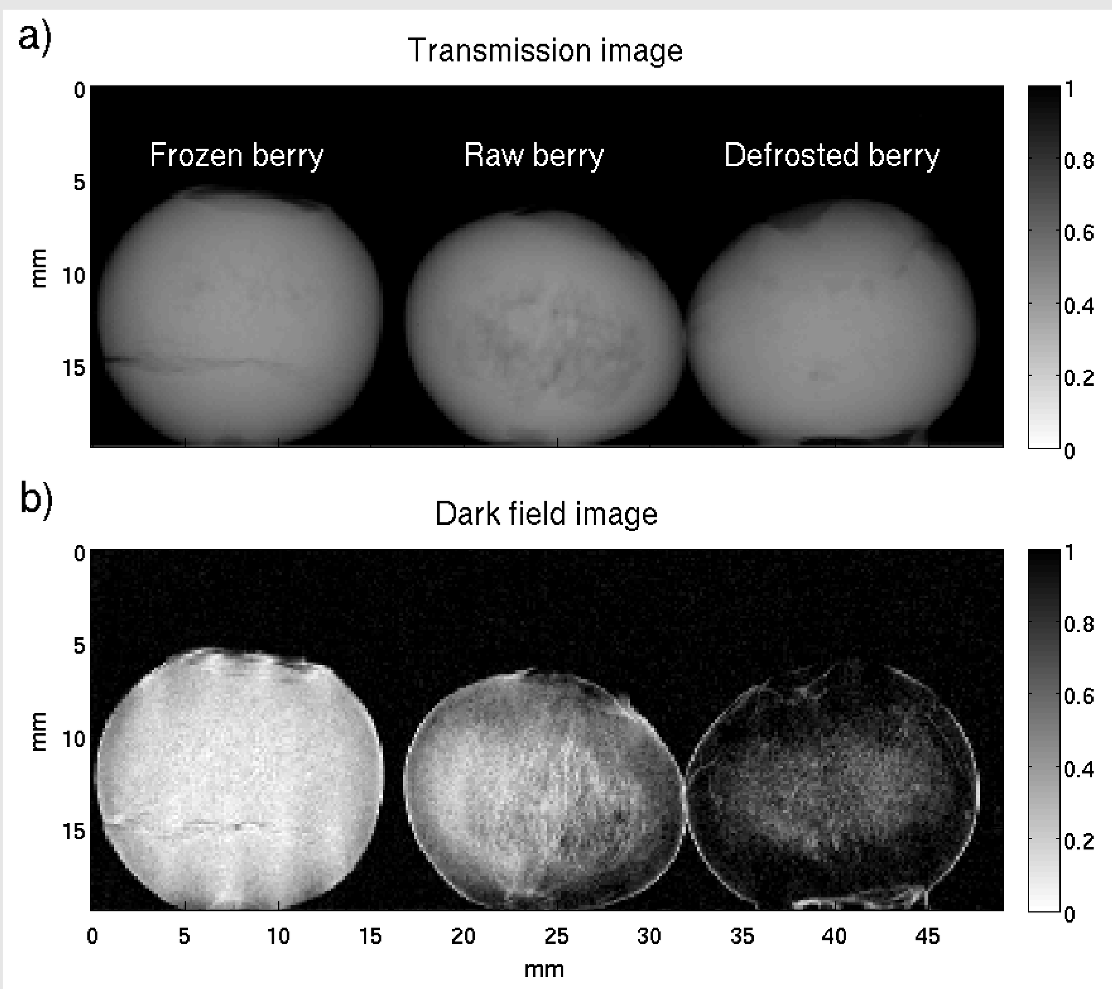


Panels a) - b) show absorption tomographic slices of a piece raw and boiled bovine meat, respectively. By comparing with the phase-contrast slices in panels c) and d), it Is seen that the contrast between muscle tissue, connective tissue and water is improved vastly. Using phase-contrast it is seen that the connective tissue has absorbed water during heating whereas the muscle protein has lost water.



In panel e), phase-contrast histograms of the raw and boiled meat are shown which again demonstrates that major changes are visible.

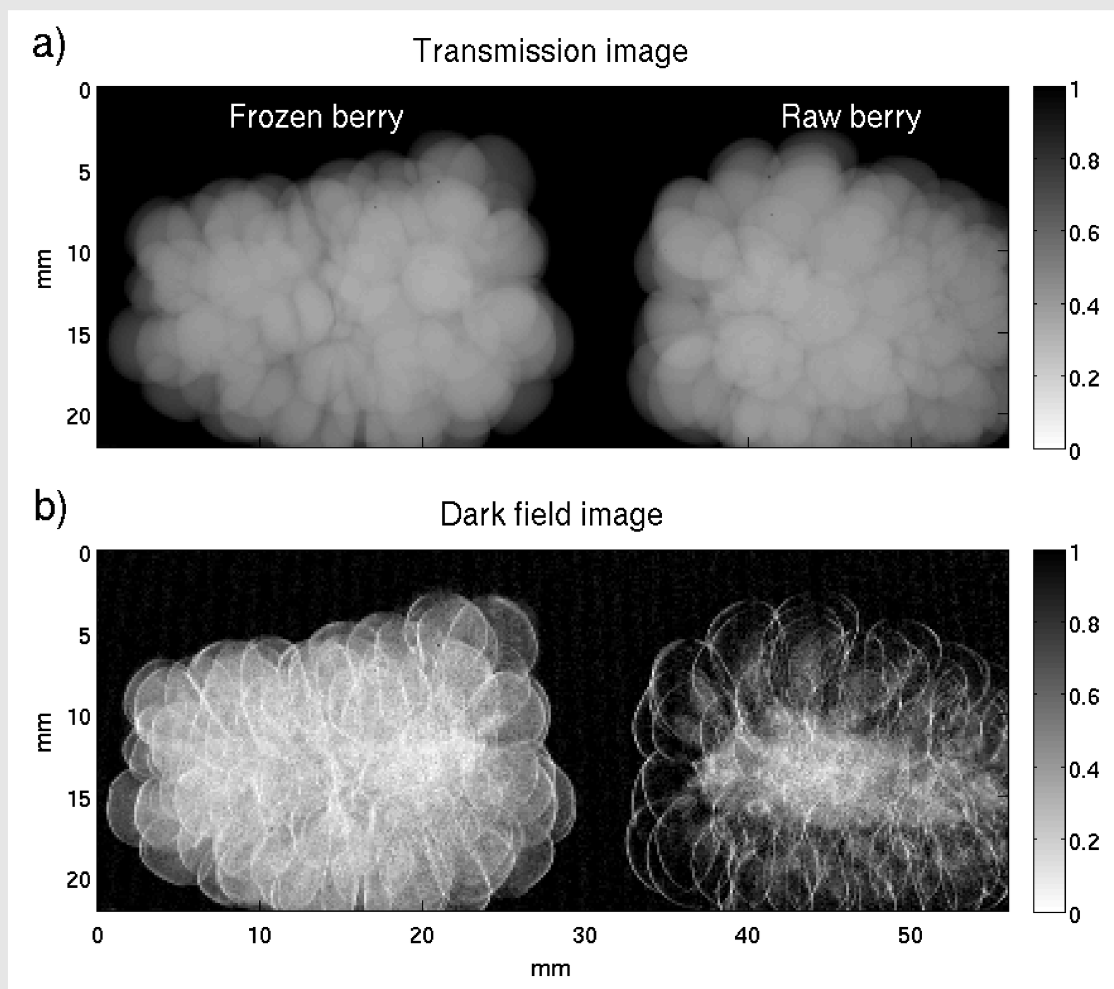
Detecting frozen berries



Frost damages to fruit will cause the fruit to be discarded and is of concern to producers. However, frost damages can be quite difficult to detect in a non-destructive way.

Using dark-field imaging, micro structural changes in berries due to freezing can be detected which are absent in standard X-ray images.[3] *Left:* Blue berries *Right:* Black berries

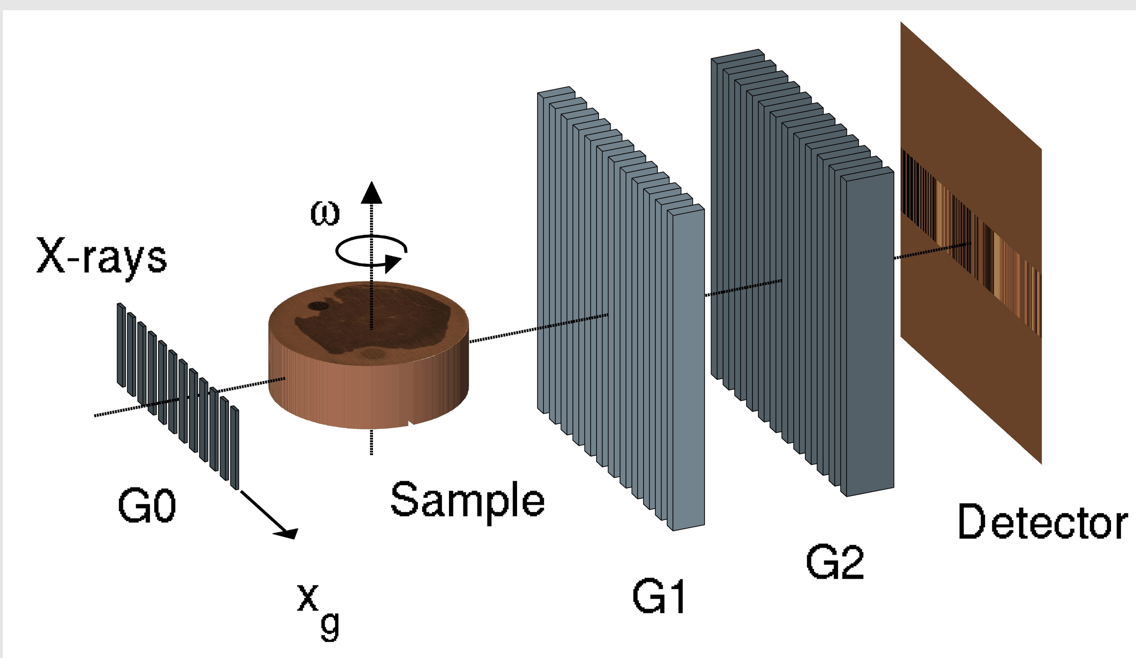
In the dark-field images, CNR values in the range from 2.0 – 2.9 are found between raw and frozen/defrosted berries. For the transmission images the CNR values are 0.1 – 0.2.



The method

A grating-based x-ray interferometer uses an interference pattern to increase sensitivity towards refraction effects and enable imaging of ultra small-angle X-ray scattering (USAXS).

The interferometer consists of a phase-grating, G1, which creates a periodic intensity modulation, and an absorption grating, G2, which is used to analyse changes in the interference pattern, by stepping one of the gratings through the pattern, recording an image at each step. [2]



At laboratory-based setups a third grating, G0, is included to assure satisfactory coherence in the x-direction. A rotation sample stage can be included for tomography.

The tomograms of cow meat were obtained at the TOMCAT beamline at PSI using 25 keV X-rays at 3rd fractonal Talbot distance.

The projections of berries were obtained using a lab source at 40 kV /150 mA at 5th Talbot distance (optimized for 28 keV)..

References

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[3] M.S. Nielsen et al (2014). Frozen and defrosted fruit revealed with X-ray dark-field radiography. *Food Control,* **39,** 222-226